APPENDIX A

EXTRACT FROM REGULATION 12, CHAPTER V OF THE IMO-SOLAS (1974) CONVENTION AS AMENDED TO 1983

THE REQUIREMENT TO CARRY RADAR AND ARPA

Ships of 500 gross tonnage and upwards constructed on or after 1 September 1984 and ships of 1600 gross tonnage and upwards constructed before 1 September 1984 shall be fitted with a radar installation.

Ships of 1000 gross tonnage and upwards shall be fitted with two radar installations, each capable of being operated independently of the other.

Facilities for plotting radar readings shall be provided on the navigating bridge of ships required by paragraph (g) or (h) to be fitted with a radar installation. In ships of 1600 gross tonage and upwards constructed on or after 1 September 1984, the plotting facilities shall be at least as effective as a reflection plotter.

An automatic radar plotting aid shall be fitted on:

1. Ships of 10,000 gross tonnage and upwards, constructed on or after 1 September 1984;
2. Tankers constructed before 1 September 1984 as follows:
   (a) If of 40,000 gross tonnage and upwards, by 1 January 1985;
   (b) If of 10,000 gross tonnage and upwards, but less than 40,000 gross tonnage, by 1 September 1986;
3. Ships constructed before 1 September 1984, that are not tankers, as follows:
   (a) If of 40,000 gross tonnage and upwards, by 1 September 1986;
   (b) If of 20,000 gross tonnage and upwards, but less than 40,000 gross tonnage, by 1 September 1987;
   (c) If of 15,000 gross tonnage and upwards, but less than 20,000 gross tonnage, by 1 September 1998.

(ii) Automatic radar plotting aids fitted prior to 1 September 1984 which do not fully conform to the performance standards adopted by the organization may, at the discretion of the administration, be retained until 1 January 1991.

(iii) the administration may exempt ships from the requirements of this paragraph, in cases where it considers it unreasonable or unnecessary for such equipment to be carried, or when the ships will be taken permanently out of service within two years of the appropriate implementation date.

EXTRACT FROM IMO RESOLUTIONS A222(VII), A278(VII), A477(XII)

Performance Standards for Navigational Radar equipment installed before 1 September 1984

INTRODUCTION

The radar equipment required by Regulation 12 of Chapter V should provide an indication in relation to the ship of the position of other surface craft and obstructions of buoys, shorelines and navigational marks in a manner which will assist in avoiding collision and navigation.

It should comply with the following minimum requirements:

Range Performance

The operational requirement under normal propagation conditions, when the radar aerial is mounted at a height of 15 meters above sea level, is that the equipment should give a clear indication of:

Coastlines:
- At 20 nautical miles when the ground rises to 60 meters,
- At 7 nautical miles when the ground rises to 6 meters.

Surface objects:
- At 7 nautical miles a ship of 5,000 gross tonnage, whatever her aspect,
- At 2 nautical miles an object such as a navigational buoy having an effective echoing area of approximately 10 square meters,
- At 3 nautical miles a small ship of length 10 meters.

Minimum Range

The surface objects specified in paragraph 2(a) (ii) should be clearly displayed from a minimum range of 50 meters up to a range of 1 nautical mile, without adjustment of controls other than the range selector.

Display

The equipment should provide a relative plan display of not less than 180 mm effective diameter.

The equipment should be provided with at least five ranges, the smallest of which is not more than 1 nautical mile and the greatest of which is not less than 24 nautical miles. The scales should preferably of 1:2 ratio. Additional ranges may be provided.

Positive indication should be given of the range of view displayed and the interval between range rings.

Range Measurement

The primary means provided for range measurement should be fixed electronic range rings. There should be at least four range rings displayed on each of the ranges mentioned in paragraph 2(c)(ii), except that on ranges below 1 nautical mile range rings should be displayed at intervals of 0.25 nautical mile.

Fixed range rings should enable the range of an object, whose echo lies on a range ring, to be measured with an error not exceeding 1.5 per cent of the maximum range of the scale in use, or 70 meters, whichever is greater.

Any additional means of measuring range should have an error not exceeding 2.5 per cent of the maximum range of the displayed scale in use, or 120 meters, whichever is the greater.

Heading Indicator

The heading of the ship should be indicated by a line on the display with a maximum error not greater than +/- 1°. The thickness of the display heading line should not be greater than 0.5°.

Provision should be made to switch off the heading indicator by a device which cannot be left in the “heading marker off” position.

Bearing Measurement

Provision should be made to obtain quickly the bearing of any object whose echo appears on the display.

The means provided for obtaining bearings should enable the bearing of a target whose echo appears at the edge of the display to be measured with an accuracy of +/- 1° or better.

Discrimination

The equipment should display as separate indications, on the shortest range scale provided, two objects on the same azimuth separated by not more than 50 meters in range.

The equipment should display as separate indications two objects at the same range separated by not more than 2.5° in azimuth.

The equipment should be designed to avoid, as far as is practicable, the display of spurious echoes.

Roll

The performance of the equipment should be such that when the ship is rolling +/- 10° the echoes of the targets remain visible on the display.

Scan

The scan should be continuous and automatic through 360° of azimuth. The target data rate should be at least 12 per minute. The equipment should operate satisfactorily in relative wind speeds of 100 knots.

Azimuth Stabilization

Means should be provided to enable the display to be stabilized in azimuth by a transmitting compass. The accuracy of alignment with the compass transmission should be within 0.5 with a compass rotation rate of 2 r.p.m.

The equipment should operate satisfactorily for relative bearings when the compass control is inoperative or not fitted.

Performance Check

Means should be available, while the equipment is used operationally, to determine readily a significant drop in performance relative to a calibration standard established at the time of installation.

Anti-clutter Devices

Means should be provided to minimize the display of unwanted responses from precipitation and the sea.

Operation

The equipment should be capable of being switched on and operated from the main display position.

Operational controls should be accessible and easy to identify and use.

After switching on from the cold, the equipment should become fully operational within 4 minutes.

A standby condition should be provided from which the equipment can be brought to a fully operational condition within 1 minute.

Interference

After installation and adjustment on board, the bearing accuracy should be maintained without further adjustment irrespective of the variation of external magnetic fields.

Sea or Ground Stabilization

Sea or ground stabilization, if provided, should not degrade the accuracy of the display below the requirements of these performance standards, and the view ahead on the display should not be unduly restricted by the use of this facility.

Siting of the Aerial

The aerial system should be installed in such a manner that the efficiency of the display is not impaired by the close proximity of the aerial to other objects. In particular, blind sectors in the forward direction should be avoided.

Performance Standards for Navigational Radar equipment installed on or after 1 September 1984

Application

This Recommendation applies to all ships' radar equipment installed on or after 1 September 1984 in compliance with Regulation 12, Chapter V of the International Convention for the Safety of Life at Sea, 1974, as amended.

Radar equipment installed before 1 September 1984 should comply at least with the performance standards recommended in resolution A.222(VII).

General

The radar equipment should provide an indication, in relation to the ship, of the position of the other surface craft and obstructions and of buoys, shorelines and navigational marks in a manner which will assist in navigation and in avoiding collision.

All radar installations

All radar installations should comply with the following minimum requirements.

Range performance

The operational requirement under normal propagation conditions, when the radar antenna is mounted at a height of 15 meters above sea level, is that the equipment should in the absence of clutter give a clear indication of:

Coastlines:

At 20 nautical miles when the ground rises to 60 meters

At 7 nautical miles when the ground rises to 6 meters.

Surface objects:

At 7 nautical miles a ship of 5000 gross tonage, whatever her aspect

At 3 nautical miles a small ship of 10 meters in length

At 2 nautical miles an object such as a navigational buoy having an effective echoing area of approximately 10 square meters.

Minimum Range

The surface objects specified in paragraph 3.1.2 should be clearly displayed from a minimum range of 50 meters up to a range of 1 nautical mile, without changing the setting of controls other than the range selector.

Display

The equipment should without external magnification provide a relative plan display in the head up unstabilized mode with an effective diameter of not less than:

180 millimeters on ships of 500 gross tonnage and more but less than 1600 gross tonnage;

250 millimeters on ships of 1600 gross tonnage and more but less than 10000 gross tonnage;

340 millimeters in the case of one display and 250 millimeters in the case of the other on ships of 10000 gross tonnage and upwards.

Note: Display diameters of 180, 250 and 340 millimeters correspond respectively to 9, 12 and 16 inch cathode ray tubes.

The equipment should provide one of the two following sets of range scales of display:

1.5, 3, 6, 12, and 24 nautical miles and one range scale of not less than 0.5 and not greater than 0.8 nautical miles; or

1, 2, 4, 8, 16, and 32 nautical miles.

Additional range scales may be provided.

The range scale displayed and the distance between range rings should be clearly indicated at all times.

Range measurement

Fixed electronic range rings should be provided for range measurements as follows:

> Where range scales are provided in accordance with paragraph 3.3.2.1, on the range scale of between 0.5 and 0.8 nautical miles at least two range rings should be provided and on each of the other range scales six range rings should be provided; or
>
> Where range scales are provided in accordance with paragraph 3.3.2.2, four range rings should be provided on each of the range scales.

A variable electronic range marker should be provided with a numeric readout of range.

The fixed range rings and the variable range marker should enable the range of an object to be measured with an error not exceeding 1.5 per cent of the maximum range of the scale in use, or 70 meters, whichever is greater.

It should be possible to vary the brilliance of the range rings and the variable range marker and to remove them completely from the display.

Heading indicator

The heading indicator of the ship should be indicated by a line on the display with a maximum error not greater than +/- 1° .The thickness of the displayed heading line should not be greater than 0.5°.

Provision should be made to switch off the heading indicator by a device which cannot be left in the “heading marker off” position.

Bearing measurement

Provision should be made to obtain quickly the bearing of any object whose echo appears on the display.

The means provided for obtaining bearing should enable the bearing of a target whose echo appears at the edge of the display to be measured with an accuracy of +/-° or better.

Discrimination

The equipment should be capable of displaying as separate indications on a range scale of 2 nautical miles or less, two similar targets at a range of between 50% and 100% of the range scale in use, and on the same azimuth, separated by not more than 50 meters in range.

The equipment should be capable of displaying as separate indications two small similar targets both situated at the same range between 50 per cent and 100% of the 1.5 or 2 mile range scales, and separated by not more than 2.5° in azimuth.

Roll or pitch

The performance of the equipment should be such that when the ship is rolling or pitching up to +/- 10° the range performance requirements of paragraphs 3.1 and 3.2 continue to be met.

Scan

The scan should be clockwise, continuous and automatic through 360° of azimuth. The scan rate should be not less than 12 r.p.m. The equipment should operate satisfactorily in relative wind speed of up to 100 knots.

Azimuth stabilization

Means should be provided to enable the display to be stabilized in azimuth by a transmitting compass. The equipment should be provided with a compass input to enable it to be stabilized in azimuth. The accuracy of alignment with the compass transmission should be within 0.5° with a compass rotation rate of 2 r.p.m.

The equipment should operate satisfactorily in the unstabilized mode when the compass control is inoperative.

Performance check

Means should be available, while the equipment is used operationally, to determine readily a significant drop in performance relative to a calibration standard established at the time of installation, and that the equipment is correctly tuned in the absence of targets.

Anti-clutter devices

Suitable means should be provided for the suppression of unwanted echoes from sea clutter, rain and other forms of precipitation, clouds and sandstorms. It should be possible to adjust manually and continuously the anti-clutter controls. Anti-clutter controls should be inoperative in the fully anti-clockwise positions. In addition, automatic anti-clutter controls may be provided; however, they must be capable of being switched off.

Operation

The equipment should be capable of being switched on and operated from the display position.

Operational controls should be accessible and easy to identify and use. Where symbols are used they should comply with the recommendations of the organization on symbols for controls on marine navigational radar equipment.

After switching on from cold the equipment should become fully operational within 4 minutes.

A standby condition should be provided from which the equipment can be brought to an operational condition within 15 seconds.

Interference

After installation and adjustment on board, the bearing accuracy as prescribed in these performance standards should be maintained without further adjustment irrespective of the movement of the ship in the earth's magnetic field.

Sea or ground stabilization (true motion display)

Where sea or ground stabilization is provided the accuracy and discrimination of the display should be at least equivalent to that required by these performance standards.

The motion of the trace origin should not, except under manual override conditions, continue to a point beyond 75 per cent of the radius of the display. Automatic resetting may be provided.

Antenna system

The antenna system should be installed in such a manner that the design efficiency of the radar system is not substantially impaired.

Operation with radar beacons

All radars operating in the 3cm band should be capable of operating in a horizontally polarized mode.

It should be possible to switch off those signal processing facilities which might prevent a radar beacon from being shown on the radar display.

Multiple radar installations

Where two radars are required to be carried they should be so installed that each radar can be operated individually and both can be operated simultaneously without being dependent upon one another. When an emergency source of electrical power is provided in accordance with the appropriate requirements of Chapter II-1 of the 1974 SOLAS convention, both radars should be capable of being operated from this source.

Where two radars are fitted, interswitching facilities may be provided to improve the flexibility and overall radar installation. They should be so installed that failure of either radar would not cause the supply of electrical energy to the other radar to be interrupted or adversely affected.

APPENDIX B

GLOSSARY AND ABBREVIATIONS

across-the-scope
A radar contact whose direction of relative motion is perpendicular to the direction of the heading flash indicator of the radar. Also called LIMBO CONTACT.

advance
The distance a vessel moves in its original direction after the helm is put over.

AFC
Automatic frequency control.

aerial
Antenna.

afterglow
The slowly decaying luminescence of the screen of the cathode-ray tube after excitation by an electron beam has ceased. See PERSISTENCE.

amplify
To increase the strength of a radar signal or echo.

antenna
A conductor or system of conductors consisting of horn and reflector used for radiating or receiving radar waves. Also called AERIAL.

anti-clutter control
A means for reducing or eliminating interferences from sea return and weather.

apparent wind
See RELATIVE WIND.

ARPA
Automatic radar plotting aid.

attenuation
The decrease in the strength of a radar wave resulting from absorption, scattering, and reflection by the medium through which it passes (waveguide, atmosphere) and by obstructions in its path. Also attenuation of the wave may be the result of artificial means, such as the inclusion of an attenuator in the circuitry or by placing an absorbing device in the path of the wave.

automatic frequency control (AFC)
An electronic means for preventing drift in radio frequency or maintaining the frequency within specified limits. The AFC maintains the local oscillator of the radar on the frequency necessary to obtain a constant or near constant difference in the frequency of the radar echo (magnetron frequency) and the local oscillator frequency.

azimuth
While this term is frequently used for bearing in radar applications, the term azimuth is usually restricted to the direction of celestial bodies among marine navigators.

azimuth-stabilized PPI
See STABILIZED PPI.

beam width
The angular width of a radar beam between half-power points. See LOBE.

bearing
The direction of the line of sight from the radar antenna to the contact. Sometimes called AZIMUTH although in marine usage the latter term is usually restricted to the directions of celestial bodies.

bearing cursor
The radial line inscribed on a transparent disk which can be rotated manually about an axis coincident with the center of the PPI. It is used for bearing determination. Other lines inscribed parallel to the radial line have many useful purposes in radar plotting.

blind sector
A sector on the radarscope in which radar echoes cannot be received because of an obstruction near the antenna. See SHADOW SECTOR.

cathode-ray tube (CRT)
The radarscope (picture tube) within which a stream of electrons is directed against a fluorescent screen (PPI). On the face of the tube or screen (PPI), light is emitted at the points where the electrons strike.

challenger
See INTERROGATOR.

circle spacing
The distance in yards between successive whole numbered circles. Unless otherwise designated, it is always 1,000 yards.

clutter
Unwanted radar echoes reflected from heavy rain, snow, waves, etc., which may obscure relatively large areas on the radarscope.

cone of courses
Mathematically calculated limits, relative to datum, within which a submarine must be in order to intercept the torpedo danger zone.

contact
Any echo detected on the radarscope not evaluated as clutter or as a false echo.

contrast
The difference in intensity of illumination of the radarscope between radar images and the background of the screen.

corner reflector
See RADAR REFLECTOR.

CPA
Closest point of approach.

course
Direction of actual movement relative to true north.

cross-band racon
A racon which transmits at a frequency not within the marine radar frequency band. To be able to use this type of racon, the ship's radar receiver must be capable of being tuned to the frequency of the cross-band racon or special accessory equipment is required. In either case, the radarscope will be blank except for the racon signal. See IN-BAND RACON.

CRT
Cathode-ray tube.

crystal
A crystalline substance which allows electric current to pass in only one direction.

datum
In Anti-submarine Warfare (ASW), the last known position of an enemy submarine at a specified time. (Lacking other knowledge this is the position and time of torpedoing.)

definition
The clarity and fidelity of the detail of radar images on the radarscope. A combination of good resolution and focus adjustment is required for good definition.

distance circles
Circles concentric to the formation center, with radii of specified distances, used in the designation of main body stations in a circular formation. Circles are designated by means of their radii, in thousands of yards from the formation center.

double stabilization
The stabilization of a Heading-Upward PPI display to North. The cathode-ray tube with the PPI display stabilized to North is rotated to keep ship's heading upward.

down-the-scope
A radar contact whose direction of relative motion is generally in the opposite direction of the heading flash indicator of the radar.

DRM
Direction of relative movement. The direction of movement of the maneuvering ship relative to the reference ship, always in the direction of $M_1 \rightarrow M_2 \rightarrow M_3 \rightarrow$...

duct
A layer within the atmosphere where refraction and reflection results in the trapping of radar waves, and consequently their propagation over abnormally long distances. Ducts are associated with temperature inversions in the atmosphere.

EBL
Electronic bearing line.

echo
The radar signal reflected back to the antenna by an object; the image of the reflected signal on the radarscope. Also called RETURN.

echo box
A cavity, resonant at the transmitted frequency which produces an artificial radar target signal for tuning or testing the overall performance of a radar set. The oscillations developed in the resonant cavity will be greater at higher power outputs of the transmitter.

echo box performance monitor
An accessory which is used for tuning the radar receiver and checking overall performance by visual inspection. An artificial echo as received from the echo box will appear as a narrow plume from the center of the PPI. The length of this plume as compared with its length when the radar is known to be operating at a high performance level is indicative of the current performance level.

face
The viewing surface (PPI) of a cathode-ray tube. The inner surface of the face is coated with a fluorescent layer which emits light under the impact of a stream of electrons. Also called SCREEN.

fast time constant (FTC) circuit
An electronic circuit designed to reduce the undesirable effects of clutter. With the FTC circuit in operation, only the nearer edge of an echo having a long time duration is displayed on the radarscope. The use of this circuit tends to reduce saturation of the scope which could be caused by clutter.

fictitious ship
An imaginary ship, presumed to maintain constant course and speed, substituted for a maneuvering ship which alters course and speed.

fluorescence
Emission of light or other radiant energy as a result of and only during absorption of radiation from some other source. An example is the glowing of the screen of a cathode-ray tube during bombardment by a stream of electrons. The continued emission of light after absorption of radiation is called PHOSPHORESCENCE.

formation axis
An arbitrarily selected direction from which all bearings used in the designation of main body stations in a circular formation are measured. The formation axis is always indicated as a true direction from the formation center.

formation center
The arbitrarily selected point of origin for the polar coordinate system, around which a circular formation is formed. It is designated “station Zero”.

formation guide
A ship designated by the OTC as guide, and with reference to which all ships in the formation maintain position. The guide may or may not be at the formation center.

FTC
Fast time constant.

gain (RCVR) control
A control used to increase or decrease the sensitivity of the receiver (RCVR). This control, analogous to the volume control of a broadcast receiver, regulates the intensity of the echoes displayed on the radarscope.

geographical plot
A plot of the actual movements of objects (ships) with respect to the earth. Also called NAVIGATIONAL PLOT.

heading flash
An illuminated radial line on the PPI for indicating own ship’s heading on the bearing dial. Also called HEADING MARKER.

heading-upward display
See UNSTABILIZED DISPLAY.

in-band racon
A racon which transmits in the marine radar frequency band, e.g., the 3-centimeter band. The transmitter sweeps through a range of frequencies within the band to insure that a radar receiver tuned to a particular frequency within the band will be able to detect the signal. See CROSS-BAND RACON.

intensity control
A control for regulating the intensity of background illumination on the radarscope. Also called BRILLIANCE CONTROL.

interference
Unwanted and confusing signals or patterns produced on the radarscope by another radar or transmitter on the same frequency, and more rarely, by the effects of nearby electrical equipment or machinery, or by atmospheric phenomena.

interrogator
A radar transmitter which sends out a pulse that triggers a transponder. An interrogator is usually combined in a single unit with a responsor, which receives the reply from a transponder and produces an output suitable for feeding a display system; the combined unit is called an INTERROGATOR-RESPONSOR.

IRP
Image retaining panel.

kilohertz (kHz)
A frequency of one thousand cycles per second. See MEGAHERTZ.

limbo contacts
See ACROSS-THE-SCOPE.

limited lines of approach
Mathematically calculated limits, relative to the force, within which an attacking submarine must be in order that it can reach the torpedo danger zone

lobe
Of the three-dimensional radiation pattern transmitted by a directional antenna, one of the portions within which the field strength or power is everywhere greater than a selected value. The half-power level is used frequently as this reference value. The direction of the axis of the major lobe of the radiation pattern is the direction of maximum radiation. See SIDE LOBES.

maneuvering ship (*M*)
Any moving unit except the reference ship.

MCPA
Minutes to closest point of approach.

megacycle per second (Mc)
A frequency of one million cycles per second. The equivalent term MEGAHERTZ (MHz) is now coming into more frequent use.

megahertz
A frequency of one million cycles per second. See KILOHERTZ.

microsecond
One millionth of 1 second.

microwaves
Commonly, very short radio waves having wavelengths of 1 millimeter to 30 centimeters. While the limits of the microwave region are not clearly defined, they are generally considered to be the region in which radar operates.

minor lobes
Side lobes.

missile danger zone
An area which the submarine must enter in order to be within maximum effective missile firing range.

MRM
Miles of relative movement. The distance along the relative movement line between any two specified points or times. Also called RELATIVE DISTANCE.

nanosecond
One billionth of 1 second.

north-upward display
See STABILIZED DISPLAY.

NRML
New relative movement line.

paint
The bright area on the PPI resulting from the brightening of the sweep by the echoes. Also, the act of forming the bright area on the PPI by the sweep.

persistence
A measure of the time of decay of the luminescence of the face of the cathode-ray tube after excitation by the stream of electrons has ceased. Relatively slow decay is indicative of high persistence. Persistence is the length of time during which phosphorescence takes place.

phosphorescence
Emission of light without sensible heat, particularly as a result of, but continuing after, absorption of radiation from some other source. An example is the glowing of the screen of a cathode-ray tube after the beam of electrons has moved to another part of the screen. It is this property that results in the chartlike picture which gives the PPI its principal value. PERSISTENCE is the length of time during which phosphorescence takes place. The emission of light or other radiant

energy as a result of and only during absorption of radiation from some other source is called FLUORESCENCE.

plan position indicator (PPI)
The face or screen of a cathode-ray tube on which radar images appear in correct relation to each other, so that the scope face presents a chartlike representation of the area about the antenna, the direction of a contact or target being represented by the direction of its echo from the center and its range by its distance from the center.

plotting head
Reflection plotter.

polarization
The orientation in space of the electric axis, of a radar wave. This electric axis, which is at right angles to the magnetic axis, may be either horizontal, vertical, or circular. With circular polarization, the axis rotate, resulting in a spiral transmission of the radar wave. Circular polarization is used for reducing rain clutter.

PPI
Plan position indicator.

pulse
An extremely short burst of radar wave transmission followed by a relatively long period of no transmission.

pulse duration
Pulse length.

pulse length
The time duration, measured in microseconds, of a single radar pulse. Also called PULSE DURATION.

pulse recurrence rate (PRR)
Pulse repetition rate.

pulse repetition rate (PRR)
The number of pulses transmitted per second.

racon
A radar beacon which, when triggered by a ship's radar signal, transmits a reply which provides the range and bearing to the beacon on the PPI display of the ship. The reply may be coded for identification purposes; in which case, it will consist of a series of concentric arcs on the PPI. The range is the measurement on the PPI to the arc nearest its center; the bearing is the middle of the racon arcs. If the reply is not coded, the racon signal will appear as a radial line extending from just beyond the reflected echo of the racon installation or from just beyond the point where the echo would be painted if detected. See IN-BAND RACON, CROSS-BAND RACON, RAMARK.

radar indicator
A unit of a radar set which provides a visual indication of radar echoes received, using a cathode-ray tube for such indication. Besides the cathode-ray tube, the radar indicator is comprised of sweep and calibration circuits, and associated power supplies.

radar receiver
A unit of a radar set which demodulates received radar echoes, amplifies the echoes, and delivers them to the radar indicator. The radar receiver differs from the usual superheterodyne communications receiver in that its sensitivity is much greater; it has a better signal to noise ratio, and it is designed to pass a pulse type signal.

radar reflector
A metal device designed for reflecting strong echoes of impinging radar signals towards their source. The *corner reflector* consists of three mutually perpendicular metal plates. Corner reflectors are sometimes assembled in clusters to insure good echo returns from all directions.

radar repeater
A unit which duplicates the PPI display at a location remote from the main radar indicator installation. Also called PPI REPEATER, REMOTE PPI.

radar transmitter
A unit of a radar set in which the radio-frequency power is generated and the pulse is modulated. The modulator of the transmitter provides the timing trigger for the radar indicator.

ramark
A radar beacon which continuously transmits a signal appearing as a radial line on the PPI, indicating the direction of the beacon from the ship. For identification purposes, the radial line may be formed by a series of dots or dashes. The radial line appears even if the beacon is outside the range for which the radar is set, as long as the radar receiver is within the power range of the beacon. Unlike the RACON, the ramark does not provide the range to the beacon.

range markers
Equally spaced concentric rings of light on the PPI which permit the radar observer to determine the range to a contact in accordance with the range setting or the range of the outer rings. See VARIABLE RANGE MARKER.

range selector
A control for selecting the range setting for the radar indicator.

RCVR
Short for RECEIVER.

reference ship (*R*)
The ship to which the movement of others is referred.

reflection plotter
An attachment fitted to a PPI which provides a plotting surface permitting radar plotting without parallax errors. Any mark made on the plotting surface will be reflected on the radarscope directly below. Also called PLOTTING HEAD.

refraction
The bending of the radar beam in passing obliquely through regions of the atmosphere of different densities.

relative motion display
A type of radarscope display in which the position of own ship is fixed at the center of the PPI and all detected objects or contacts move relative to own ship. See TRUE MOTION DISPLAY.

relative movement line
The locus of positions occupied by the maneuvering ship relative to the reference ship.

relative plot
The plot of the positions occupied by the maneuvering ship relative to the reference ship.

relative vector
A velocity vector which depicts the relative movement of an object (ship) in motion with respect to another object (ship), usually in motion.

relative wind
The speed and relative direction from which the wind appears to blow with reference to a moving point. See APPARENT WIND.

remote PPI
Radar repeater.

resolution
The degree of ability of a radar set to indicate separately the echoes of two contacts in range, bearing, and elevation. With respect to:

range - the minimum range difference between separate contacts at the same bearing which will allow both to appear as separate, distinct echoes on the PPI.

bearing - the minimum angular separation between two contacts at the same range which will allow both to appear as separate, distinct echoes on the PPI.

elevation - the minimum angular separation in a vertical plane between two contacts at the same range and bearing which will allow both to appear as separate, distinct echoes on the PPI.

responder beacon
Transponder beacon.

RML
Relative movement line.

scan
To investigate an area or space by varying the direction of the radar antenna and thus the radar beam. Normally, scanning is done by continuous rotation of the antenna.

scanner
A unit of a radar set consisting of the antenna and drive assembly for rotating the antenna.

scope
Short for RADARSCOPE.

screen
The face of a cathode-ray tube on which radar images are displayed.

screen axis
An arbitrarily selected direction from which all bearings used in the designation of screen stations in a circular formation are measured. The screen axis is always indicated as a true direction from the screen center.

screen center
The selected point of origin for the polar coordinate system, around which a screen is formed. The screen center usually coincides with the

formation center, but may be a specified true bearing and distance from it.

screen station numbering
Screening stations are designated by means of a “station number”, consisting of four or more digits. The last three digits are the bearing of the screening station relative to the screen axis, while the prefixed digits indicate the radius of the distance circle in thousands of yards from the screen center.

sea return
Clutter on the radarscope which is the result of the radar signal being reflected from the sea, especially near the ship.

sensitivity time control (STC)
An electronic circuit designed to reduce automatically the sensitivity of the receiver to nearby targets. Also called SWEPT GAIN CONTROL.

shadow sector
A sector on the radarscope in which the appearance of radar echoes is improbable because of an obstruction near the antenna. While both *blind* and *shadow* sectors have the same basic cause, *blind* sectors generally occur at the larger angles subtended by the obstruction. See BLIND SECTOR.

side lobes
Unwanted lobes of a radiation pattern, i.e., lobes other than major lobes. Also called MINOR LOBES.

speed triangle
The usual designation of the VECTOR DIAGRAM when scaled in knots.

SRM
Speed of relative movement. The speed of the maneuvering ship relative to the reference ship.

stabilized display (North-Upward)
A PPI display in which the orientation of the relative motion presentation is fixed to an unchanging reference (North). This display is North-Upward, normally. In an UNSTABILIZED DISPLAY, the orientation of the relative motion presentation changes with changes in ship’s heading. See DOUBLE STABILIZATION.

stabilized PPI
See STABILIZED DISPLAY.

station numbering
Positions in a circular formation (other than the formation center) are designated by means of a “station number,” consisting of four or more digits. The last three digits are the bearing of the station relative to the formation axis, while the prefixed digits indicate the radius of the distance circle in thousands of yards. Thus, station 4090 indicates a position bearing 90 degrees relative to the formation axis on a distance circle with a radius of 4,000 yards from the formation center.

STC
Sensitivity time control.

strobe
Variable range marker.

sweep
As determined by the time base or range calibration, the radial movement of the stream of electrons impinging on the face of the cathode-ray tube. The origin of the sweep is the center of the face of the cathode-ray tube or PPI. Because of the very high speed of movement of the point of impingement, the successive points of impingement appear as a continuously luminous line. The line rotates in synchronism with the radar antenna. If an echo is received during the time of radial travel of the electron stream from the center to the outer edge of the face of the tube, the sweep will be increased in brightness at the point of travel of the electron stream corresponding to the range of the contact from which the echo is received. Since the sweep rotates in synchronism with the radar antenna, this increased brightness will occur on the bearing from which the echo is received. With this increased brightness and the persistence of the tube face, paint corresponding to the object being “illuminated” by the radar beam appears on the PPI.

swept gain control
Sensitivity time control.

TCPA
Time to closest point of approach.

time line
A line joining the heads of two vectors which represent successive courses and speeds of a specific unit in passing from an initial to a final position in known time, via a specified intermediate point. This line also touches the head of a constructive unit which proceeds directly from the initial to the final position in the same time. By general usage this constructive unit is called the fictitious ship. The head of its vector divides the time line into segments inversely proportional to the times

spent by the unit on the first and second legs. The time line is used in two-course problems.

torpedo danger zone
An area which the submarine must enter in order to be within maximum effective torpedo firing range.

trace
The luminous line resulting from the movement of the points of impingement of the electron stream on the face of the cathode-ray tube. See SWEEP.

transfer
The distance a vessel moves perpendicular to its initial direction in making a turn.

transponder A transmitter-receiver capable of accepting the challenge (radar signal) of an interrogator and automatically transmitting an appropriate reply. See RACON.

transponder beacon
A beacon having a transponder. Also called RESPONDER BEACON.

trigger
A sharp voltage pulse usually of from 0.1 to 0.4 microseconds duration, which is applied to the modulator tubes to fire the transmitter, and which is applied simultaneously to the sweep generator to start the electron beam moving radially from the sweep origin to the edge of the face of the cathode-ray tube.

true motion display
A type of radarscope display in which own ship and other moving contacts move on the PPI in accordance with their true courses and speed. This display is similar to a navigational (geographical) plot. See RELATIVE MOTION DISPLAY.

true vector
A velocity vector which depicts actual movement with respect to the earth.

true wind
True direction and force of wind relative to a fixed point on the earth.

unstabilized display (Heading-Upward)
A PPI display in which the orientation of the relative motion presentation is set to ship's heading and, thus, changes with changes in ship's heading. In this *Heading-Upward* display, radar echoes are shown at their relative bearings. A true bearing dial which is continuously set to ship's course at the 000 degrees relative bearing is normally used with this display for determining true bearings. This true bearing dial may be either manually or automatically set to ship's course. When set automatically by a course input from the gyrocompass, the true bearing dial is sometimes called a STABILIZED AZIMUTH SCALE. The latter term which appears in manufacturer's instruction books and operating manuals is more in conformity with air navigation rather than marine navigation usage. See DOUBLE STABILIZATION.

up-the-scope
A radar contact whose direction of relative motion is generally in the same direction as the heading flash indicator of the radar.

variable range marker
A luminous range circle or ring on the PPI, the radius of which is continuously adjustable. The range setting of this marker is read on the range counter of the radar indicator.

vector
A directed line segment representing direction and magnitude.

vector diagram
A graphical means of adding and subtracting vectors. When the vector magnitude is scaled in knots, this diagram is usually called SPEED TRIANGLE.

velocity vector
A vector the magnitude of which represents rate of movement; a velocity vector may be either true or relative depending upon whether it depicts actual movement with respect to the earth or the relative movement of an object (ship) in motion with respect to another object (ship).

VRM
Variable range marker.

VTS
Vessel traffic system.

XMTR
Short for TRANSMITTER.

APPENDIX C

RELATIVE MOTION PROBLEMS

RAPID RADAR PLOTTING PROBLEMS

1. Own ship, on course 311˚, speed 17 knots, obtains the following radar bearings and ranges at the times indicated, using a radar setting of 24 miles:

Time	*Bearing*	*Range (mi.)*
1136	280˚	16.0
1142	274˚	13.6
1148	265˚	11.4

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) Direction of relative movement (DRM)

Solution:

(1) R 8.2 mi., (2) T 1204.5, (3) DRM 131˚.

2. Own ship, on course 000˚, speed 12 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0410	035˚	11.1
0416	031˚	9.2
0422	025˚	7.3

Required:

(1) Distance at which the contact will cross dead ahead.

(2) Direction of relative movement (DRM).

(3) Speed of relative movement (SRM); relative speed.

(4) Range at CPA.

(5) Bearing of contact at CPA.

(6) Relative distance (MRM) from 0422 position of contact to the CPA.

(7) Time at CPA.

(8) Distance own ship travels from the time of the first plot (0410) to the time of the last plot (0422) of the contact.

(9) True course of the contact.

(10) Actual distance traveled by the contact between 0410 and 0422.

(11) True speed of the contact.

Solution:

Assuming that the contact maintains course and speed: (1) D 4.3. mi., (2) DRM 234˚, (3) SRM 20 kn., (4) R 3.5 mi., (5) B 324˚, (6) MRM 6.5 mi., (7) T 0441, (8) D 2.4 mi., (9) C 270˚, (10) D 3.2 mi., (11) S 16 kn.

3. Own ship, on course 030˚, speed 23 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
1020	081˚	10.8
1023	082˚	9.2
1026	083˚	7.7

Required:

(1) Range at CPA.

(2) Bearing of contact at CPA.

(3) Speed of relative movement (SRM); relative speed.

(4) Time at CPA.

(5) Distance own ship travels from the time of the first plot (1020) to the time of the last plot (1026) of the contact; distance own ship travels in 6 minutes.

(6) True course of the contact.

(7) Actual distance traveled by the contact between 1020 and 1026.

(8) True speed of the contact.

(9) Assuming that the contact has turned on its running lights during daylight hours because of inclement weather, what side light(s) might be seen at CPA?

Solution:

Assuming that the contact maintains course and speed: (1) R 1.0 mi., (2) B 167˚, (3) SRM 32 kn., (4) T 1041, (5) D 2.3 mi., (6) C 304˚, (7) D 2.2 mi., (8) S 22 kn., (9) starboard (green) side light.

4. Own ship, on course 000˚, speed 11 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
1100	080˚	12.0
1106	080˚	10.8
1112	080˚	9.6

Required:

(1) Range at CPA.

(2) Speed of relative movement (SRM); relative speed.

(3) Time at CPA.

(4) True course of contact.

Decision:

When the range to the contact decreases to 6 miles, own ship will change course so that the contact will pass safely ahead with a CPA of 2.0 miles.

Required:

(5) New course for own ship.

(6) New SRM after course change.

Solution:

Assuming that the contact maintains course and speed: (1) Nil; risk of collision exists, (2) SRM 12 kn., (3) T 1200, (4) 307˚, (5) 063˚, (6) New SRM 22 kn.

5. Own ship, on course 220˚, speed 12 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0300	297˚	11.7
0306	296˚	10.0
0312	295˚	8.5

Required:

(1) Range at CPA.

(2) Speed of relative movement (SRM); relative speed.

(3) Time at CPA.

(4) True course of contact.

Decision:

When the range to the contact decreases to 6 miles, own ship will change course so that the contact will clear ahead, in minimum time, with a CPA of 3.0 miles.

Required:

(5) New course for own ship.

(6) New SRM after course change.

Solution:

Assuming that the contact maintains course and speed: (1) R 1.2 mi., (2) SRM 16.5 kn., (3) T 0343, (4) C 161˚, (5) Come right to 290˚, (6) New SRM 28 kn.

6. Own ship, on course 316˚, speed 21 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
1206	357˚	11.8
1212	358˚	10.2
1218	359˚	8.7

Required:

(1) Range at CPA.

(2) Speed of relative movement (SRM); relative speed.

(3) True course of contact.

(4) True speed of contact.

Decision:

When the range to the contact decreases to 6 miles, own ship will change course so that the contact will clear ahead, in minimum time, with a CPA of 3 miles.

Required:

(5) New course for own ship.

Solution:

Assuming that the contact maintains course and speed:(1) R 1.1 mi., (2) SRM 15.5 kn., (3) C 269˚, (4) S 12.5 kn., (5) C 002˚.

7. Own ship, on course 000°, speed 10 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0400	010°	11.1
0406	010°	9.0
0412	010°	7.1

Required:

(1) Range at CPA.

(2) Speed of relative movement (SRM); relative speed.

(3) Time at CPA.

(4) True course of contact.

(5) True speed of contact.

Decision:

Own ship will change course at 0418 so that the contact will clear ahead (on own ship's port side), with a CPA of 2 miles.

Required:

(6) New course for own ship.

Solution:

Assuming that the contact maintains course and speed: (1) Nil., (2) SRM 20 kn., (3) T 0433, (4) C 200°, (5) S 10 kn., (6) C 046°.

8. Own ship, on course 052°, speed 15 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 24 miles:

Time	*Bearing*	*Range (mi.)*
0340	052°	14.9
0346	052°	11.6
0352	052°	8.3

Required:

(1) Range at CPA.

(2) True course of contact.

(3) Assuming that there are no other vessels in the area and that the contact is a large passenger ship, clearly visible at 0352, is this a crossing, meeting, or overtaking situation?

(4) True speed of contact.

Decision:

A decision is made to change course when the range to the contact decreases to 6 miles.

(5) New course of own ship to clear the contact port to port with a CPA of 3 miles.

Solution:

Assuming that the contact maintains course and speed: (1) Nil; risk of collision exists, (2) C 232°, (3) Meeting, (4) S 18 kn., (5) C 119°.

9. Own ship, on course 070˚, speed 16 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0306	015˚	10.8
0312	016˚	8.3
0318	017˚	5.9

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) True course of the contact.

(4) True speed of the contact.

Decision:

When the range to the contact decreases to 5 miles, own ship will change speed only so that contact will clear ahead at a distance of 3 miles.

Required:

(5) New speed of own ship.

Solution:

Assuming that the contact maintains course and speed: (1) R 0.5 mi., (2) T 0333., (3) C 152˚, (4) S 21 kn., (5) S $3^1/_4$ kn.

10. Own ship, on course 093˚, speed 18 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0452	112˚	5.9
0458	120˚	4.2
0504	137˚	2.7

Required:

(1) Range at CPA.

(2) Relative distance (MRM) from 0452 to 0504 position of contact.

(3) Speed of relative movement (SRM); relative speed.

(4) Direction of relative movement (DRM).

(5) Distance own ship travels from the time of the first plot (0452) to the time of the last plot (0504) of the contact.

(6) True course and speed of the contact.

Solution:

Assuming that the contact maintains course and speed: (1) R 1.9 mi., (2) MRM 3.6 mi., (3) SRM 18 kn., (4) DRM 273˚, (5) D 3.6 mi., (6) The contact is either a stationary object or a vessel underway but with no way on.

11. Own ship, on course 315˚, speed 11 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 24 miles:

Time	*Bearing*	*Range (mi.)*
0405	319˚	17.8
0417	320˚	15.6
0429	321˚	13.4

Required:

(1) Range at CPA.

(2) True course and speed of the contact.

Decision:

When the range to the contact decreases to 8 miles, own ship will change course so that the contact will pass safely to starboard with a CPA of 3 miles.

Required:

(3) New course for own ship.

Solution:

Assuming that the contact maintains course and speed: (1) R 1.6 mi., (2) The contact is either stationary or a vessel with little or no way on. (3) C 303˚.

12. Own ship, on course 342˚ speed 11 knots, (half speed), obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0906	287˚	12.0
0912	287˚	10.2
0918	288˚	8.4

Required:

(1) Range at CPA.

(2) True course of the contact.

(3) True speed of the contact.

(4) Is this a crossing, meeting, or overtaking situation?

Decision:

Own ship is accelerating to full speed of 18 knots and will change course at 0924 when the speed is 15 knots so that the contact will clear astern with a CPA of 2 miles.

Required:

(5) New course for own ship.

Solution:

Assuming that the contact maintains course and speed: (1) R 0.5 mi., (2) C 067˚, (3) S 15 kn., (4) Crossing, (5) C 006˚.

13. Own ship, on course 350˚, speed 18 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0200	030˚	10.0
0203	029˚	8.7
0206	028˚	7.4

Required:

(1) Range at CPA.

(2) True course of the contact.

(3) True speed of the contact.

Decision:

When the range to the contact decreases to 6 miles, own ship changes course to 039˚.

Required:

(4) New range at CPA.

(5) Describe how the new time at CPA would be computed.

(6) New time at CPA.

(7) At what bearing and range to the contact can own ship safely resume the original course of 350˚ and obtain a CPA of 3 miles?

(8) What would be the benefit, if any, of bringing own ship slowly back to the original course of 350˚ once the point referred to in (7) above is reached?

Solution:

Assuming that the contact maintains course and speed: (1) R 1.0 mi., (2) C 252˚, (3) S 18.5 kn., (4) R 3.0 mi., (5) Determine the original relative speed (SRM); then using it, determine the time at Mx. Next, determine the new SRM; then using it, determine how long it will take for the contact to move in relative motion down the new RML from Mx to the new CPA. (6) T 0219, (7) When the contact bears 318˚, range 3.0 miles. (8) The slow return to the original course will serve to insure that the contact will remain outside the 3-mile danger or buffer zone after own ship is steady on 350˚.

14. Own ship, on course 330˚, speed 20 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0608	300˚	12.0
0614	300˚	10.0
0620	300˚	8.0

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) True course of the contact.

(4) True speed of the contact.

(5) What danger, if any, would be present if own ship maintained course and speed and contact changed course to 120˚ at 0620?

Decision:

Assume that the contact maintains its original course and speed and that own ship's speed has been reduced to 11.5 knots when the range to the contact has decreased to 6 miles.

Required:

(6) New range at CPA.

(7) Will the contact pass ahead or astern of own ship?

Solution:

(1) Nil; risk of collision exists. (2) T 0644, (3) C 045˚, (4) S 10.5 kn., (5) None, (6) R 2.0 mi., (7) Ahead.

15. Own ship, on course 022˚, speed 32 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 24 miles:

Time	*Contact A*	*Contact B*	*Contact C*
0423	070˚-23.2 mi.	170˚-23.8 mi.	025˚-22.6 mi.
0426	070˚-21.1 mi.	170˚-23.8 mi.	023˚-21.2 mi.
0429	070˚-19.1 mi.	170˚-23.8 mi.	020˚-19.0 mi.

The observations are made on a warm, summer morning. The weather is calm; the sea state is 0. From sea water temperature measurements and weather reports, it is determined that the temperature of the air immediately above the sea is 12˚ F cooler than the air 300 feet above the ship. Also, the relative humidity immediately above the sea is 30% greater than at 300 feet above the ship.

Required:

(1) Since the contacts are detected at ranges longer than normal, to what do you attribute the radar's increased detection capability?

(2) Ranges at CPA for the three contacts.

(3) True courses of the contacts.

(4) True speeds of the contacts.

(5) Which contact presents the greatest threat?

(6) If own ship has adequate sea room, should own ship come left or right of contact A?

Decision:

When the range to contact A decreases to 12 miles, own ship will change course so that no contact will pass within 4 miles.

Required:

(7) New course for own ship.

Solution:

Assuming that the contacts maintain course and speed: (1) Super-refraction, (2) Contact A-nil; Contact B-R 23.8 mi.; Contact C-R 9.2 mi., (3) Contact A-C 299˚; Contact B-C 022˚; Contact C-C 282˚, (4) Contact A-S 30 kn; Contact B-S 32 kn.; Contact C-S 19 kn., (5) Contact A; it is on collision course, (6) Come right, (7) C 063˚.

16. Own ship, on course 120˚, speed 12 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Contact A*	*Contact B*	*Contact C*
0300	095˚-8.7 mi.	128˚-10.0 mi.	160˚-7.7 mi.
0306	093˚-7.8 mi.	128˚-8.3 mi.	164˚-7.0 mi.
0312	090˚-7.0 mi.	128˚-6.6 mi.	170˚-6.3 mi.

Required:

(1) Ranges at CPA for the three contacts.

(2) True courses of the contacts.

(3) Which contact presents the greatest danger?

(4) Which contact, if any, might be a lightship at anchor?

Decision:

When the range to contact B decreases to 6 miles, own ship will change course to 190˚.

Required:

(5) At what time will the range to contact B be 6 miles?

(6) New CPA of contact C after course change to 190˚.

Solution:

Assuming the contacts maintain course and speed: (1) Contact A-R 3.0 mi.; contact B-nil; contact C-R 4.3 mi., (2) contact A-C 138˚; contact B-C 329˚; contact C-C 101˚, (3) Contact B; it is on collision course, (4) None, (5) T 0314, (6) R 3.2 mi.

17. Own ship, on course 298˚, speed 13 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
0639	267˚	19.0
0651	266.5˚	16.0
0709	265˚	11.5
0729	261˚	6.5
0735	255.5˚	4.9
0737	252˚	4.3
0741	242.5˚	3.3

Required:

(1) Range at CPA as determined at 0729.

(2) Time at CPA as determined at 0729.

(3) Course of other ship as determined at 0729.

(4) Speed of other ship as determined at 0729.

(5) Range at CPA as determined at 0741.

(6) Time at CPA as determined at 0741.

(7) Course of other ship as determined at 0741.

(8) Speed of other ship as determined at 0741.

Solution:

(1) R 1.0 mi., (2) T 0755, (3) C 030˚, (4) S 7.0 kn., (5) R 2.0 mi., (6) T 0749.5, (7) C 064˚, (8) S 7.0 kn.

18. Own ship, on course 073˚, speed 19.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
1530	343˚	16.2
1540	343˚	14.7
1546	343˚	13.8
1558	343˚	12.0
1606	342.5˚	10.9
1612	341.5˚	10.1
1624	339.5˚	8.4
1632.5	336˚	7.3
1644	328.5˚	6.0
1657	315˚	4.7

Required:

(1) Range at CPA as determined at 1558.

(2) Time at CPA as determined at 1558.

(3) Course of other ship as determined at 1558.

(4) Speed of other ship as determined at 1558.

(5) Range at CPA as determined at 1624.

(6) Time at CPA as determined at 1624.

(7) Course of other ship as determined at 1624.

(8) Speed of other ship as determined at 1624.

(9) Range at CPA as determined at 1657.

(10) Time at CPA as determined at 1657.

(11) Course of other ship as determined at 1657.

(12) Speed of other ship as determined at 1657.

Solution:

(1) R 0.0 mi., (2) T 1718, (3) C 098˚, (4) S 21.5 kn., (5) R 2.0 mi., (6) T 1721, (7) C 098˚, (8) S 20.0 kn., (9) R 3.7 mi., (10) T 1718, (11) C 098˚, (12) S 18.0 kn.

19. Own ship, on course 140˚, speed 5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
0257	142˚	10.5
0303	141.5˚	8
0308	141˚	6
0312	135˚	4.5
0314	126.5˚	4
0317	110.5˚	3.2

Required:

(1) Range at CPA as determined at 0308.

(2) Time at CPA as determined at 0308.

(3) Course of other ship as determined at 0308.

(4) Speed of other ship as determined at 0308.

(5) Range at CPA as determined at 0317.

(6) Time at CPA as determined at 0317.

(7) Course of other ship as determined at 0317.

(8) Speed of other ship as determined at 0317.

Solution:

(1) R 0.2 mi., (2) T 0322, (3) C 325˚, (4) S 20.0 kn., (5) R 3.0 mi., (6) T 0320, (7) C 006˚, (8) S 20.0 kn.

20. Own ship, on course 001˚, speed 15 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 15 miles:

Time	*Bearing*	*Range (mi.)*
2243	138˚	14.0
2255	137.5˚	12.6
2318	136˚	9.9
2332	140˚	8.0
2351	166.5˚	5.5
0002.5	191.5˚	5.0
0008	204˚	5.1
0014	214˚	5.1
0020	222˚	4.95
0026	230˚	4.85

Required:

(1) Range at CPA as determined at 2318.

(2) Time at CPA as determined at 2318.

(3) Course of other ship as determined at 2318.

(4) Speed of other ship as determined at 2318.

(5) Predicted range of other vessel as it crosses dead ahead of own ship as determined at 2318.

(6) Predicted time of crossing ahead as determined at 2318.

(7) Course of other ship as determined at 2351.

(8) Speed of other ship as determined at 2351.

(9) Predicted range of other vessel as it crosses dead astern of own ship as determined at 2351.

(10) Predicted time of crossing astern as determined at 2351.

(11) Direction of relative movement between 0002.5 and 0008.

(12) Relative speed between 0002.5 and 0008.

(13) Course of other ship as determined at 0026.

(14) Speed of other ship as determined at 0026.

Solution:

(1) R 1.2 mi., (2) T 0042, (3) C 349˚, (4) S 21.0 kn., (5) R 2.0 mi., (6) T 0056, (7) C 326˚, (8) S 21.0 kn., (9) R 5.1 mi., (10) T 2358, (11) DRM 281.5˚, (12) SRM 12.0 kn., (13) C 349˚, (14) S 21.0 kn.

21. Own ship, on course 196°, speed 8 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 12 miles:

Time	*Bearing*	*Range (mi.)*
2303	016°	11.0
2309	016°	10.0
2318	016°	8.5
2330	016°	6.5
2340	011.5°	4.9
2350	359.5°	3.4
2400	333.5°	2.2
0010.5	286°	2.0
0020	247.5°	2.5
0026	233.5°	3.2

Required:

(1) Range at CPA as determined at 2318.

(2) Time at CPA as determined at 2318.

(3) Course of other ship as determined at 2318.

(4) Speed of other ship as determined at 2318.

(5) Range at CPA as determined at 2400.

(6) Time at CPA as determined at 2400.

(7) Course of other ship as determined at 2400.

(8) Speed of other ship as determined at 2400.

(9) Course of other ship as determined at 0026.

(10) Speed of other ship as determined at 0026.

Solution:

(1) R 0.0 mi., (2) T 0009, (3) C 196°, (4) S 18.0 kn., (5) R 2.0 mi., (6) T 0006, (7) C 207°, (8) S 18.0 kn., (9) C 196°, (10) S 18.0 kn.

22. Own ship, on course 092°, speed 12 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 16 miles:

Time	*Bearing*	*Range (mi.)*
1720	335°	15.0
1750	334.5°	11.7
1830	333°	7.2
1854	325.5°	4.5
1858	315.5°	4.0
1902	303.5°	3.6
1906	289.5°	3.4
1914	263.5°	3.3
1930	212.5°	3.8
1950	184.5°	6.8

Required:

(1) Range at CPA as determined at 1830.

(2) Time at CPA as determined at 1830.

(3) Course of other ship as determined at 1830.

(4) Speed of other ship as determined at 1830.

(5) Course of other ship as determined at 1906.

(6) Speed of other ship as determined at 1906.

(7) Course of other ship as determined at 1950.

(8) Speed of other ship as determined at 1950.

Solution:

(1) R 0.5 mi., (2) T 1935.5, (3) C 114°, (4) S 16.0 kn., (5) C 147°, (6) S 16.0 kn., (7) C 124°, (8) S 20.0 kn.

23. Own ship, on course 080˚, speed 12.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 16 miles:

Time	*Bearing*	*Range (mi.)*
0035	038˚	14.5
0044	038.5˚	13.2
0106	040˚	10.0

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) Course of other ship.

(4) Speed of other ship.

Decision:

When the range decreases to 8.0 miles, own ship will turn to the left to increase the CPA distance to 3.0 miles.

Required:

(5) Predicted time of change of course.

(6) Predicted bearing of other ship when own ship changes course.

(7) New course for own ship.

(8) Time at new CPA.

(9) Time at which own ship is dead astern of other ship.

Solution:

(1) R 1.0 mi., (2) T 0215, (3) C 124˚, (4) S 9.0 kn., (5) T 0120, (6) B 041.5˚, (7) C 064˚, (8) T 0200, (9) T 0204.

24. Own ship, on course 251˚, speed 18.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
0327	314˚	16.2
0337	314.5˚	14.7
0351	315˚	12.6
0401	315.5˚	11.1
0413.5	315˚	9.1
0422	305˚	6.7

Required: (As determined at 0401.)

(1) Range at CPA.

(2) Time at CPA.

(3) Course of other ship.

(4) Speed of other ship.

Decision:

Own ship will pass astern of other vessel, with a CPA of 4.0 miles and new direction of relative movement perpendicular to own ship's original course, maintaining a speed of 18.5 knots. The original course will be resumed when the other ship is dead ahead of this course.

Required:

(5) New direction of relative movement.

(6) Predicted time of change of course.

(7) Predicted bearing of other ship when own ship changes course.

(8) Predicted range of other ship when own ship changes course.

(9) New course for own ship.

(10) Predicted new relative speed.

(11) Predicted time at which other ship is dead ahead of own ship.

(12) Predicted range of other ship when it is dead ahead of own ship.

(13) Predicted time at CPA, as determined at 0422.

(14) Bearing of other ship when it is dead ahead of own ship's original course.

(15) Predicted time of resuming original course.

Solution:

(1) R 1.0 mi., (2) T 0515, (3) C 222˚, (4) S 16.0 kn., (5) DRM 161˚, (6) T 0411, (7) B 316.5˚, (8) R 9.6 mi., (9) C 292˚, (10) SRM 19.8 kn., (11) T 0428, (12) R 5.3 mi., (13) T 0438.5, (14) B 251˚, (15) T 0438.5.

25. Own ship, on course 035˚, speed 20 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 15 miles:

Time	*Bearing*	*Range (mi.)*
1900	035˚	14.4
1906	035˚	12.8
1915	035˚	10.4
1924	035˚	8.0
1933	035˚	5.6
1941	030˚	3.5
1947	015˚	1.9

Required: (As determined at 1915.)

(1) Range at CPA.

(2) Time at CPA.

(3) Course of other ship.

(4) Speed of other ship.

Decision:

When the range decreases to 5.0 miles, own ship will change course to the right, maintaining a speed of 20 knots, to pass the other ship with a CPA of 1.0 mile. Original course of 035˚ will be resumed when the other ship is broad on the port quarter.

Required:

(5) Predicted time of change of course to the right.

(6) New course for own ship.

(7) Bearing of CPA as determined at 1935.

(8) Predicted time at 1.0 mile CPA as determined at 1935.

(9) Bearing of other ship when own ship commences turn to original course.

(10) Predicted time of resuming original course.

Solution:

(1) R 0.0 mi., (2) T 1954, (3) C 035˚, (4) S 4.0 kn., (5) T 1935, (6) C 044˚, (7) B 314˚, (8) T 1952, (9) B 269˚, (10) T 1957.

26. Own ship, on course 173˚, speed 16.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
2125.5	221˚	16.0
2130	220.5˚	15.0
2137.5	219˚	13.2
2142	218˚	12.2
2151.5	215.5˚	10.0
2158	205.5˚	8.3
2206	185˚	6.7

Required: (As determined at 2142.)

(1) Range at CPA.

(2) Time at CPA.

(3) Predicted range other ship will be dead ahead.

(4) Predicted time of crossing ahead.

(5) Course of other ship.

(6) Speed of other ship.

Decision:

When range decreases to 10 miles own ship will change course to the right to bearing of stern of other vessel (assume 0.5˚ right of radar contact).

Required:

(7) Range at new CPA.

(8) Time at new CPA.

(9) Direction of new relative movement line.

(10) New relative speed.

(11) New course of own ship.

Decision:

Own ship will resume original course when bearing of other vessel is the same as the original course of own ship.

Required:

(12) Predicted time of resuming original course.

(13) Distance displaced to right of original course line.

(14) Additional distance steamed in avoiding other vessel.

(15) Time lost in avoiding other vessel.

Solution:

(1) R 2.5 mi., (2) T 2233, (3) R 3.0 mi., (4) T 2225.5, (5) C 120˚, (6) S 14.7 kn., (7) R 6.3 mi., (8) T 2211.5, (9) DRM 075˚, (10) SRM 23.2 kn., (11) C 216˚, (12) T 2209.5, (13) D 3.4 mi., (14) D 1.3 mi., (15) t less than 5 min.

27. Own ship, on course 274˚, speed 15.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
0815	008˚	14.4
0839	006˚	10.1
0853	004˚	7.6

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) Course of other ship.

(4) Speed of other ship.

Decision:

When the range decreases to 6.0 miles, own ship will commence action to obtain a CPA distance of 4.0 miles, with own ship crossing astern of other vessel.

Required:

(5) Predicted bearing of other ship when at a range of 6.0 miles.

(6) Predicted time when other ship is at 6.0 mile range, and own ship must commence action to obtain the desired CPA of 4.0 miles.

Decision:

Own ship may (1) alter course to right and maintain speed of 15.5 knots, or (2) reduce speed and maintain course of 274˚.

Required:

(7) New course if own ship maintains speed of 15.5 knots.

(8) Predicted time when other vessel bears 274˚ and own ship's original course can be resumed.

(9) New speed if own ship maintains course of 274˚.

(10) Predicted time when other vessel crosses ahead of own ship and original speed of 15.5 knots can be resumed.

Solution:

(1) R 1.1 mi., (2) T 0935, (3) C 242˚, (4) S 20.0 kn., (5) B 002˚, (6) T 0902, (7) C 019˚, (8) T 0916, (9) S 8.2 kn., (10) T 0936.

28. Own ship, on course 052˚, speed 8.5 knots, obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
0542	052˚	18.5
0544	052˚	17.5
0549	052˚	15.0
0550	052˚	14.5

Required:

(1) Range at CPA.

(2) Time at CPA.

(3) Course of other ship.

(4) Speed of other ship.

Decision:

At 0555, own ship is to alter course to right to provide a CPA distance of 2.0 miles on own ship's port side.

Required:

(5) Predicted bearing of other ship when own ship changes course.

(6) Predicted range of other ship when own ship changes course.

(7) New course for own ship.

Own ship continues to track other ship and obtains the following radar bearings and ranges at the times indicated, using a radar range setting of 20 miles:

Time	*Bearing*	*Range (mi.)*
0559	050˚	10.0
0604.5	043.5˚	7.4
0606.5	040˚	6.5
0609	034˚	5.5

Required:

(8) Course of other ship as determined at 0609.

(9) Speed of other ship as determined at 0609.

(10) Range at CPA as determined at 0609.

Solution:

(1) R 0.0 mi., (2) T 0619, (3) C 232˚, (4) S 21.5 kn., (5) B 052˚, (6) R 12.0 mi., (7) C 086˚, (8) C 241˚, (9) S 21.5 kn., (10) R 3.0 mi.

APPENDIX D

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